CONCLUSIONS OF ESA 1ST OPTICAL WIRELESS ONBOARD COMMUNICATIONS WORKSHOP: CURRENT STATUS AND THE ROAD FORWARD

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RESUME :." Cet article est basé sur les contributions fournies par les industries de communications optiques sans fil, les industries spatiales et les universités ou instituts de recherche lors *du workshop organisé par l'ESTEC en Septembre 2004 " Optical Wireless On-board Communications Workshop"* , ainsi que les activités initiées depuis les cinq dernieres années par la section *Ordinateur et Systèmes embarqués* de l'ESA . L*e 'workshop'* mentionné ci-dessus a présenté à l'échelle Européenne l'état de l'art des techniques et des technologies *'communications optiques sans fil'* et de leur applicabilité dans le domaine spatial. De plus, cet article intègre les touts derniers résultats fournis par des projets en cours de développement et de validation.

ABSTRACT : *The bases for this paper are the inputs from the space and commercial optical wireless industries, and academia to the ESTEC sponsored " Optical Wireless On-board Communications Workshop" of September 2004, plus the activities initiated by the Computer and Data System Section of ESA over the last five years. The above-mentioned workshop has presented a complete* ***European*** *vision of the current situation of optical wireless techniques and technologies and their applicability to space.*

In addition, the presented paper will integrate the latest results available from on-going complementary development and testing projects.

1 - OBJECTIVES OF THE 1 ST OPTICAL WIRELESS ON-BOARD COMMUNICATIONS WORKSHOP

The purpose of this workshop was to bring together representatives of Space Agencies, Aerospace Industry, Wireless Technology Industry, Academic and Research Institutions and End-users involved in this field in order to:

-Review the state-of-the-art of optical free space communications in ground and in space, in short and medium link distances, point-to-point as well as broadcast or other networking schemes

-Explore the future needs, potential solutions and challenges in applying these technologies to communications on-board (spacecraft, ISS) and in ground integration and test facilities

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-Investigate the challenges imposed on by the space environment on opto-electronic component technolgies; in particular with respect to space radiation, temperature and vacuum conditions

-Conclude on the main techniques and technologies for the optical wireless intra-spacecraft LAN as a distinct spacecraft subsystem

2-WORKSHOP CONCLUSIONS

2.1-STATE OF SPACE RELATED RESEARCH AND DEVELOPMENT.

This workshop has presented a complete **European** vision of the current situation of optical wireless techniques and technologies and their applicability to space.

The work of INTA[1] and Astrium[2] has provided a clear **demonstration of feasibility** via the implementation of a fully wireless physical layer with a large number of nodes based on optical technologies. Several types of links have been demonstrated, from line-of-sight links to diffuse links, from low data rate (tens of kbps) to high data rate (hundreds of Mbps) suitable for control bus type applications.

Off-board, one of the main advantages of wireless communications may be to ease the **AIT** process[2]. Besides the obvious wiring and connectors savings introduced by the use of these technologies, non-intrusive monitoring of equipment is enabled. Nevertheless, AIT needs to be further studied: integration processes have to be set up and it has to be noted that several challenges (background light, lack of equipment and/or S/C walls, etc) will need to be overcome.

Weight is often quoted as an advantage of optical wireless communications, however this statement has to be modulated. It must also be noted that without miniaturisation, this claim does not hold true. If optical wireless is only there to replace the system bus -mil-std-1553-B, OBDH- in an existing architecture where discrete I/O are centralized (from the central computer box or from one or two Remote Terminal Units boxes) the net gain in mass is not so high, few kilograms and is dependent of the S/C topology. In a decentralised architecture where user specific I/O are distributed locally to the users (micro-RTUs), the gain will be more important. However a big step in reducing harness and its complexity, is not only the reduction of the wiring but also connections (in the order of several hundreds or thousands) to small sensors (typically thermistors) or simple actuators (relays). This is to compare with the to current effort in industry for developing sensors buses and transducers networks and systems. Obviously the target is not the suppression of all the harness -that includes anyhow power and RF- but the provision of less wired solutions on board.

One of the main obstacles of optical wireless communications is the **shortage of opto-electronic** and electronic components **tested for space use**. Many COTS components are designed and

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1 Presentation on “Optical Wireless demonstrator of intra-Satellite communications “(OWLS). INTA, Spain). Activity developed under the GS program of ESA

2 Presentation on“Validation of a wireless optical layer for on-board data communications” (EADS-Astrium &UPM-Spain). Activity developed under the GS program of ESA

manufactured to have the capabilities required, but the space community must liaise with the European opto-electronics industry to make steps towards space qualification.

Radiation remains a challenge that is very specific for components in space, however, the challenge of opto-electronics is not ionising radiation but displacement damage. Work with extremely high ionising dose rates substantiates this further. Discussions also emphasized the importance of the particle energy when comparing different test results and the space environment.

In order to simulate and calculate the **link budget**, software tools have been investigated. While Astrium[2] has used proprietary thermal software for the modeling, INTA leans towards the use of ray-tracing based tools. To improve the link budget, several approaches are possible; the widespread use of repeaters is one possibility, q-diffusion another.

From the technology side, the use of larger and more sensitive detectors could offer improvements, although they are of reduced availability. **Non-imaging optics** emerges as a very interesting technology for coupling onto detectors or even into optical fibres, allowing on the other hand the modification of emission profile at emitters.

For **large spacecraft**, repeaters are difficult to avoid. In multi-compartment spacecraft, the backbone shall probably remain electrical or optical-fiber based. For communications within each compartment, the fact that optical signals cannot pass from one-compartment to another may be a strength.

Several approaches to an **optical wireless bus** have been presented. While INTA presented a working optical bus based on the Mil-Std 1553 protocol and EADS-Astrium a similar master-slave bus built over an IrDA network, work on the IEEE 1073 (IrDA based Standard for medical applications) shows the potential of optical wireless for manned missions and astronaut training.

The effort undertaken by INTA to fly a qualified experiment on-board NANOSAT 01 at the end of last year deserves a special mention. This will constitute the first European optical wireless intra-satellite link in orbit.

2.2-TERRESTRIAL TECHNOLOGIES AND TECHNIQUES WITH POTENTIAL FOR SPACE USE.

Work has been presented on the possibility for **directional reception and transmission** of optical signals. The technology has potential for tracking moving objects and for the implementation of space-division multiplexing techniques.

‘Payload’ or ‘Distributed systems’ application, with a high rate and multi-master/peer to peer communications are envisaged possible with to-day technology developments for Aeronautics.

Exploration of new **techniques for medium access** (CDMA-DS/FH) which allow the utilization of the full bandwidth offered at optical frequencies, has been identified as a promising alternative to the still immature WDM for wireless systems, providing less expensive implementations via off-the-self electronic.

Among several possible implementations for **optical back planes**, those ones making use of free space (optical wireless) links have been identified of the utmost importance for future space instrumentation.

3-THE ROAD FORWARD

ESA and Space community are in the stage of performing detail studies of applying Optical Wireless solutions to intra-satellite communications. As a next step, those activities shall be initiated with the purpose:

-to test and adapt (when possible) COTS,

-to develop the required optoelectronic technologies that can fulfil the propagation constraints, space --requirements and including the AIT issues,

-to standardize optical wireless protocols at European level as well as international level (for example through the CCSDS area 'Spacecraft On board Interfaces Services (SOIS)'. A 'Bird of Feather'group regrouping members of different Agencies and Industry has been set up recently and has met in Toulouse in November 2004 and in Athens in April 2005.

-to study consolidated technologies for terrestrial applications having a high potential in future space systems,

-to provide convincing ground based demonstrations implementing a whole Optical Wireless Intra satellite Communications Subsystem or application in a real dimension S/C.

-to find opportunities for flight demonstrations.

This would pave the way towards the integration of 'optical wireless communications techniques' in the S/C avionics designer toolbox.

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